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**(54) Title of the Invention: A Method of Cold Compression for Removing Residual Stress**

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**Specification**

**1 Title of the Invention: A Method of Cold Compression for Removing Residual Stress**

**2 Claims**

1. A method of cold compression for removing residual stress wherein in the case that a free-forged item of heat-treated aluminum alloy is cold-compressed between the upper and lower dies of a press so as to plastically deform it in order to remove residual stress from the forged item, a lubricant is placed between the forged item and the dies, and then the cold-compression is carried out.

**3 Detailed Description Of The Invention**

**(Industrial Field of Use)**

The invention relates to a method of removing residual stress from heat-treated aluminum alloy free-forged items by cold, compression plastic deformation.

**(Prior Art)**

Free-forged aluminum alloy products are used after they have been heat-treated by such processes as solution-treatment or tempering. Therefore, there is a danger that residual stress will occur in the forged product, and that later machining will cause dimensional variation, fatigue strength loss, stress corrosion cracking, and the like.

Therefore, conventionally, heat-treated aluminum alloy free-forged products are cold compressed, and plastically deformed from 1 – 5% between an upper and lower die, to remove the residual stress.

**(Problems To Be Solved By The Invention)**

Due to the increased size of modern presses, and the development of alloys, 7050 aluminum alloys being representative, that have little susceptibility to tempering, it has become possible to forge thick items, in one piece. However, there is a problem in that when removing residual stress from a large forged item using press dies to plastically deform the item with cold compression, the lowering of the strength in the central region of the material is significant. The inventors performed the following experiments to check the affects of cold-compression plastic deformation on strength.

<sup>1</sup> As with most Japanese names, there are many "correct" readings. Although these are "correct", they may not be the actual readings.

First, a 7050 aluminum alloy ingot was forged, as shown in Figs 3, 4, into a rectangular solid block ( $t=190\text{mm}$ ,  $w=230\text{mm}$ ,  $l=30\text{mm}$ ). Next the block 1 was solution-treated at  $477\text{C}$  for  $6.5\text{hr}$  and then tempered. Then as shown in Fig 5, the upper surface 2 and the lower surface 3 of the block 1 were clamped between the top die 4 and the bottom die 5 of a press, and cold-compression plastic deformation was carried out.

Here the thickness  $t$  of the block 1 was deformed by 1%, 3%, and 5%. Then the deformation of the central region of the side of the block that was hatched in Fig 3 was shown in Fig 1. Here deformations are respectively indicated for ---O---: 1% deformation, ---Δ---: 3%, ---X---: 5%.

After cold-compression, it was aged at  $120\text{C}$  for  $24\text{hr}$ ,  $-177\text{C}$  for  $6\text{hr}$ .

A test plate 6, shown by the dotted lines in Fig 4, was extracted from the processed block 1. Tensile strength ( $\sigma_s \text{kgf/mm}^2$ ), proof stress ( $\sigma_y \text{kgf/mm}^2$ ), and elongation ( $\delta\%$ ) were measured at the following displacements from the top surface 2: 15mm, 45mm, 75mm, 110mm, 145mm, and 175mm. The results are shown in Fig 2.

According to Fig 1, in the cases of 1%, 3%, and 5% plastic deformation, the amount of deformation perpendicular to the direction of compression was small at the upper and lower surfaces 2, 3 and increased in the central region of the thickness. Also, there was less deformation at the bottom surface 3 than at the top surface 2. This is because due to the friction between the block 1 and the dies, at the top and bottom surfaces 2 and 3 that contact the dies, it is difficult for deformation to occur in a direction perpendicular to the compression, creating a section 7 indicated by the hatching in Fig 5, where it is difficult for deformation to occur. In particular, because the bottom die 5 is stationary, it is more difficult for the bottom surface of the block to deform in a direction radial from the compression than for the top surface.

As Fig 2 shows, tensile strength  $\sigma_s$  and proof stress  $\sigma_y$ , are lower toward the central region of the block 1 than at its edges. The primary cause of this is that when the block 1 is tempered, the rate of tempering is slower toward the central region of the block than at the edges, causing a strength differential. The second cause is that as stated above, the degree of deformation toward the center is greater than at the top and bottom edges that are in contact with the press dies, and therefore there is a greater amount of dislocation precipitation, causing a reduction of strength.

As a result of the aforementioned experiments, it was determined that in the case that after heat-treating, free-forged aluminum alloy is plastically deformed by cold-compression to remove residual stress, the amount of deformation at the top and bottom surfaces that contact the press dies differs from the deformation inside the material, and that this difference causes a large differential in the strength distribution in the direction of the thickness of the forged item. Additionally because there is little plastic deformation at the top and bottom surfaces of the forged item, there is insufficient residual stress reduction.

The object of the invention is to provide a method of cold compression in order to remove residual stress, wherein the deformation differential between the forged item at the surfaces that contact the press dies and its central region is reduced, thus causing a uniform strength distribution in the forged item, and uniformly removing residual stress, which makes for an item having superior strength.

#### (Means To Solve The Problems)

The technical means taken to solve these problems, are characterized such that in the case that a free-forged item of heat-treated aluminum alloy is cold-compressed between the upper and lower dies of a press so as to plastically deform it in order to remove residual stress from the forged item, a lubricant is placed between the forged item and the dies, and then the cold-compression is carried out.

#### (Operation)

A lubricant between the forged item and the dies reduces the friction between the forged item and the dies in the case of cold compression. This in turn reduces the force that prevents deformation perpendicular to compression in the region where the item contacts the dies, and reduces the amount of differential in deformation between the surface and central region of the forged item.

#### (Embodiments)

Under the same conditions mentioned above, a heat-treated 7050 aluminum alloy block 1, was cold compression between an upper die 4 and a lower die 5, plastically deforming it by 3%. In this case, as a lubricant, a Teflon sheet was placed between the block 1 and the press dies, and thereafter cold-compression was used to plastically deform in order to remove residual stress. Fig 1,<sup>2</sup> (---▲---) indicates, as before, the deformation state of the edge of block 1 toward its central

<sup>2</sup> The figure mentions an oil lubricant

region. Also Fig 2 shows, as before, the results of measuring proof stress ( $\sigma_s$  kgf/mm<sup>2</sup>) and tensile strength ( $\sigma_y$  kgf/mm<sup>2</sup>).

In the case above in which an aluminum alloy block is plastically deformed by 3% using cold-compression, when a lubricant was placed between it and the press dies, the differential in deformation between the surface of the block and its central region was reduced when compared to the case in which a lubricant was not placed between. This is because due to the lubricant, the friction between the dies and the block surfaces 2, 3 that is generated during compression is reduced, and the deformation of the surfaces in a direction perpendicular to the compression is not restricted. Therefore, as Fig 2 shows, strength too becomes uniform through the thickness of the material, and uniform plastic deformation causes the reduction in residual stress to become uniform, making for an item having superior strength.

Although in the embodiment above, Teflon sheeting was used as a lubricant, plastic films such as nylon sheeting, solid lubricants such as boron nitride powder or molybdenum disulfide powder, liquid lubricants such as colloidal graphite oil or a graphite powder oil solution may also be used. Table 1 shows the strength differences between the surface region of the aluminum alloy block and its central region in the case of using these lubricants and performing the same cold compression as above, along side data for the case in which no lubricant is used.

Amount of deformation	Lubricant	Surface region		Central region		Strength differences		Residual stress (kgf/mm <sup>2</sup> )
		$\sigma_s$ kgf/mm <sup>2</sup>	$\sigma_y$ kgf/mm <sup>2</sup>	$\sigma_s$ kgf/mm <sup>2</sup>	$\sigma_y$ kgf/mm <sup>2</sup>	$\sigma_s$ kgf/mm <sup>2</sup>	$\sigma_y$ kgf/mm <sup>2</sup>	
0		58.3	55.4	55.8	52.7	2.5	2.7	11.8
3%	None	57.7	53.9	52.4	47.1	5.3	6.8	3.0
	Teflon sheeting	56.4	51.3	54.6	48.5	1.8	2.8	2.8
	Nylon sheeting	56.8	51.5	53.8	47.9	3.0	3.6	3.5
	Boron nitride powder	56.3	50.8	53.8	47.8	2.5	3.0	3.3
	Molybdenum disulfide powder	56.5	51.5	54.2	48.6	2.3	2.9	2.7
	Colloidal graphite oil	56.1	50.5	54.4	47.9	1.7	2.6	2.9
	Graphite oil	56.9	50.8	55.1	48.1	1.8	2.7	2.6

According to the data above, compared to the case in which no lubricant is used, in the case of any of the lubricants the strength differential between the surface region and the central region was reduced, resulting in an item having superior strength.

#### (Benefits of the Invention)

According to the invention, in the case that residual stress is removed from a free-forged heat processed aluminum alloy, a lubricant is placed between the forged item and the dies. Thus the differential in deformation in the direction perpendicular to the thickness of the forged item is reduced, the strength distribution is uniform, and furthermore removal of residual stress is uniform—making it possible to obtain a product having superior strength.

#### 4. Brief Description of the Drawings

Fig 1 shows the deformed states of aluminum alloy blocks. Fig 2 shows strength and elongation for the same. Figs 3 and 4 are perspective views of the same. Fig 5 shows the compressed state of the same.

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